

SYSTEM AND METHODS TO OVERCOME GRAVITY-INDUCED DYSFUNCTION IN EXTREMITY PARESIS

[0001] The present application claims priority to U.S. Provisional Patent Application Ser. No. 60/614,928 entitled “Devices and Methods to Overcome Gravity-Induced Dysfunction in Upper Extremity Paresis”, filed Sep. 29, 2004, which is herein incorporated by reference in its entirety for all purposes.

[0002] The United States government has certain rights to this invention pursuant to Grant No. H133G030143 from the National Institutes of Disability and Rehabilitation Research to Northwestern University.

FIELD OF THE INVENTION

[0003] The invention relates to the field of rehabilitation and/or physical therapy for the treatment of injury and/or disease using a haptic system that is used to train and/or assist an individual having a neurological condition. In one aspect the invention provides an assistive robotic device in combination with a 3-dimensional virtual reality workspace. More specifically, the invention relates to a system and method to overcome gravity-induced dysfunction in upper extremity paresis.

BACKGROUND OF THE INVENTION

[0004] Disturbances in movement coordination are the least well understood but often the most debilitating with respect to functional recovery following brain injury. These deficits in coordination are expressed in the form of abnormal muscle synergies and result in limited and stereotypic movement patterns that are functionally disabling. The result of these constraints in muscle synergies is an abnormal coupling between shoulder abduction and elbow flexion in the arm, which significantly reduces a stroke survivor's reaching space when he/she lifts up the weight of the impaired arm against gravity. Current neurotherapeutic approaches to mitigate these abnormal synergies have produced, at best, limited functional recovery.

[0005] In the leg the expression of abnormal synergies results in coupling between hip/knee extension with hip adduction. The result of this is a reduced ability of activating hip abductor muscles in the impaired leg during stance.

Disturbances of Voluntary Movement in Hemiparetic Stroke

[0006] A detailed qualitative description of the abnormal movement patterns in the impaired limb, and the natural history of the evolution of the various components of these abnormal clinical signs was first provided by Twitchell in 1951, in which he delineated both the major features of the movement disturbance, and the time course of recovery from stroke (Twitchell (1951) *Brain* 74: 443-480). A prominent feature of the disturbed movement patterns was the emergence of “stereotypic” movements, in which there appeared to be a relatively tight coupling of motion at adjacent joints in the upper and lower limbs.

[0007] Brunnstrom subsequently classified these abnormal stereotypic movement patterns into so called “synergies” which were broadly of either flexor or extensor type (Brunnstrom (1970) In: “Movement therapy in hemiplegia: a neurophysiological approach” Harper & Row, Publishers

Inc., Hagerstown Md.). This qualitative classification of abnormal synergies, summarized in Table 1, has received limited modification or study by other investigators.

TABLE 1

Upper Limb synergies in hemiparetic stroke after Brunnstrom (1970, supra)	
Extension synergy	Flexion synergy
<u>Arm</u>	<u>Arm</u>
Shoulder Girdle protraction	Shoulder Girdle Retraction
adduction	abduction to 90°
internal rotation	external rotation
Elbow	Elbow
extension	Flexion
pronation	Supination
<u>Leg</u>	<u>Leg</u>
Hip	Hip
extension	extension
adduction	adduction
internal rotation	internal rotation
Knee	Knee
extension	extension

[0008] Recent treatment approaches for hemiparetic upper extremity such as “motor relearning program”, electromyographic (EMG)-triggered/functional electrical stimulation, repeated mental practice, constraint-induced movement therapy, robot-aided sensory-motor training and bilateral arm training focus on task-specific repetition, increased intensity, and/or exercise in a real-world context. (See, for example, Langhammer and Stanghelle (2000) *Clin. Rehabil.* 14: 361-369; Cauraugh et al. (2000) *Stroke* 31: 1360-1364; Page et al. (2001) *Phys. Ther.* 81: 1455-1462; Miltner et al. (1999) *Stroke* 30: 586-592; van der Lee et al. (1999) *Stroke* 30: 2369-2375; Volpe et al. (2000) *Neurology* 54: 1938-1944; Volpe et al. (1999) *Neurology* 53: 1874-1876; Whittall et al. (2000) *Stroke* 31: 2390-2395; and Richards and Pohl (1999) *Clin Geriatr Med* 15: 819-832; Woldag and Hummelsheim (2002) *J. Neurol.* 249: 518-528) Despite favorable mounting evidence for the newer treatment models, none of the current neurerehabilitation techniques directly address the presence of abnormal synergistic patterns that constrain functional reaching (Dewald et al. (2001) *Topics in Stroke Rehabilitation* 8: 1-11). Interventions that target abnormal synergistic movement patterns may ameliorate functional reaching and greatly benefit individuals with chronic stroke-induced movement discoordination.

[0009] In the lower limb recent findings from basic science provide preliminary evidence that functional locomotor recovery is possible after stroke or spinal cord injury when intense and accurate afferent input is provided in a task-specific and repetitive manner. Treadmill training is an example of a therapeutic modality that is derived from studies of adult cats with a low thoracic spinal transection who recovered the ability to step on a moving treadmill belt after they were trained on the treadmill and provided with truncal support, stimulation to recover extensor activity, and assistance in paw placement (Barbeau and Rossignol (1987) *Brain Res.* 412: 84-95; de Leon et al. (1998a) *J. Neurophysiol.* 80: 83-91; de Leon et al. (1998b) *J. Neurophysiol.* 79: 1329-1340; Lovely, et al., (1986) *Exp. Neurol.* 92: 421-435). Investigators have found that the spinal loco-